Vibration Control

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Module - 3
Vibration Isolation
Lecture - 3
Vibration Isolation – III

Hi, this is Dr. S. P. Harsha from mechanical and industrial department, IIT Roorkee. In the course of this vibration and control, we are discussing about the vibration isolators. So, in previous two chapters we mainly discussed about that how we can design the isolator, especially in terms of the passive isolators. Then, according to the system applications and the system design, how we can put these isolators or how we can choose these isolators.

Specially, whether we need to go with the springs, we need to go with the damper or the mass itself or even the in combination, these things which we decide, which we discussed. And even we discussed about, that whether the system is exciting at lower frequency, at higher frequencies or at the resonant frequencies. Then, how do we choose these things? What are the critical locations, where we can place these isolators.

So, in previous chapters you see you know like, we discussed, we discussed about the rigid body. When we can say that, the foundation which is the basic transmitting media of these vibrations, is termed as the rigid body. Or even you see here when the frequencies are going beyond certain level, then we can say the foundation is not the rigid foundation or the rigid body sometimes, it is a flexible body or the foundation itself.

So, we discussed all about you see the insertion losses, the design aspect. And you see here, when we are saying that yeah this is my perfect isolator, then certainly you see the insertion losses, which are computed based on the velocity or the force incoming and out outgoing. We can perfectly design the system to minimize these losses. So, in this particular lecture, we are going to discuss about the same concept, but in numerical way we, we, we are going to solve some numerical problem based on, those concepts which we discussed in the previous lecture.

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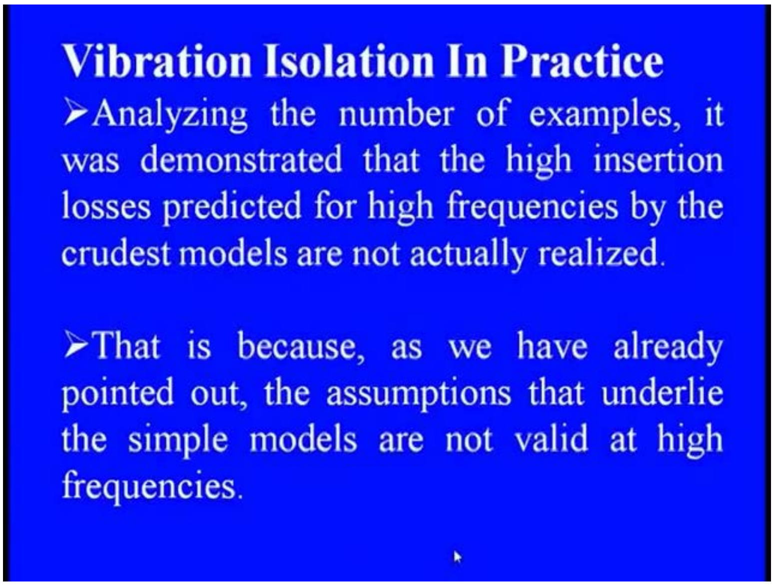

So, when we are saying that the vibration isolators then, we need to see that whether the system is exciting at the lower frequency, at the higher frequency or at, what exactly the forcing frequency is there, along with the natural frequency of the system. So, analyzing the number of examples, it is demonstrated that the high insertion losses predicted, for high frequency by crudest models and they are not basically realized in that way. And it is mainly because of, we have seen that there are lots of assumptions which we are making and they are making you see, the systems so simple that the realistic feature of the system is too far. Specially, in terms of the high frequencies and in other way also, we are keeping say you see, we are just designing isolator based on our damping.

So, we are just going with the damper or whatever you see, the isolator is there in that, but sometimes the damping which is coming out, from the system is of a complex nature. So, that is why you see here, when we are saying that the, we are saying you know like, the insertion losses are these, these, they are not accurate in their own way. So, machines and foundations, which we are assuming that the rigid, they are not rigid and sometimes you see here, they are not even compliant. There is no compliance in between the machines and foundation and whatever the isolators, which we are keeping there.

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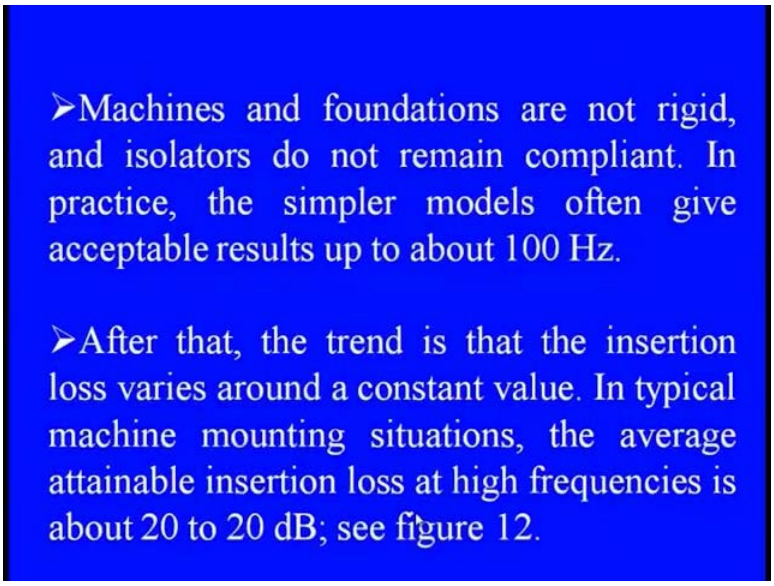

So, as you see when we are modeling those things, using the simple model or with the lots of assumptions, the acceptance level of the frequency range is almost near about, the 100 hertz. And the trend of this insertion losses, always varies around the constant value or else, if you want to compute the insertion losses in terms of the decibel sound, then we know that the insertion losses at the higher frequencies is almost something about, which is average attainable you see here, is 20 to 50 dB around that.

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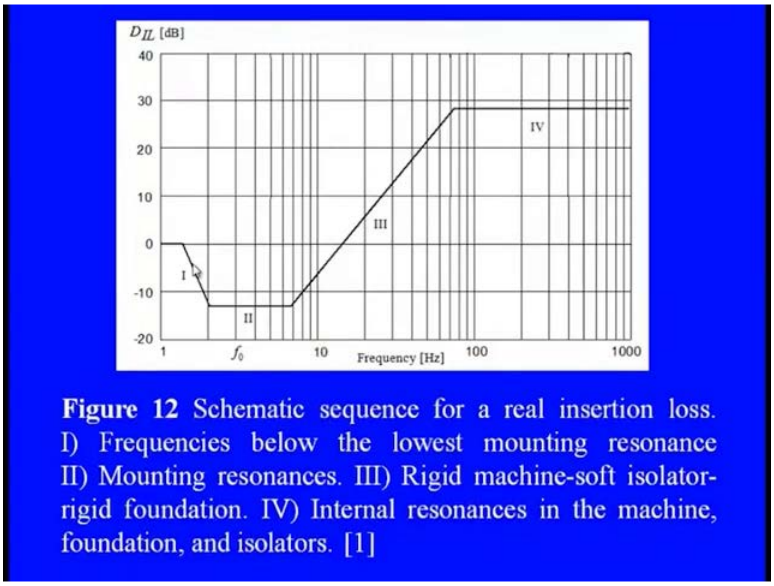

Figure 12 Schematic sequence for a real insertion loss. I) Frequencies below the lowest mounting resonance II) Mounting resonances. III) Rigid machine-soft isolator-rigid foundation. IV) Internal resonances in the machine, foundation, and isolators. [1]

So, we can see that you see, when we are trying to vary it is going from minus 20 to almost 30 dB. And the variation is like that, in which, in this particular diagram we are simply you know like, viewing that a sequence for the real insertion loss. The first part, there are you see, the four reasons which are clearly showing in that, the first reason is simply the phenomena of the frequency, which is below the lowest mounting resonance.

So, you can see that when we are just starting with the frequency, the insertion loss is starting from we can say the 0 and then, they are absolutely going down, below the lowest mounting resonance. Then, when we are approaching to the mounting resonance, there is a stable criteria towards that. And once the rigid foundation start forming, then we can say that the rigid machine with this soft isolator, in those rigid foundation, the insertion losses are being increasing. And when they are increasing up to certain level, then the internal resonances of the machine with the foundation and isolators are coming and they are showing its own nature.

So, this variation is clearly showing that, how the frequencies are being varied with the insertion losses and what other parameters like, the resonances, like you see, you know like the foundation. And especially, when the forcing and internal feature of the system are when, you know like connected towards, connected together, the system parameter. Then how the variations are there especially, in the frequency, exciting frequency and the insertion losses.

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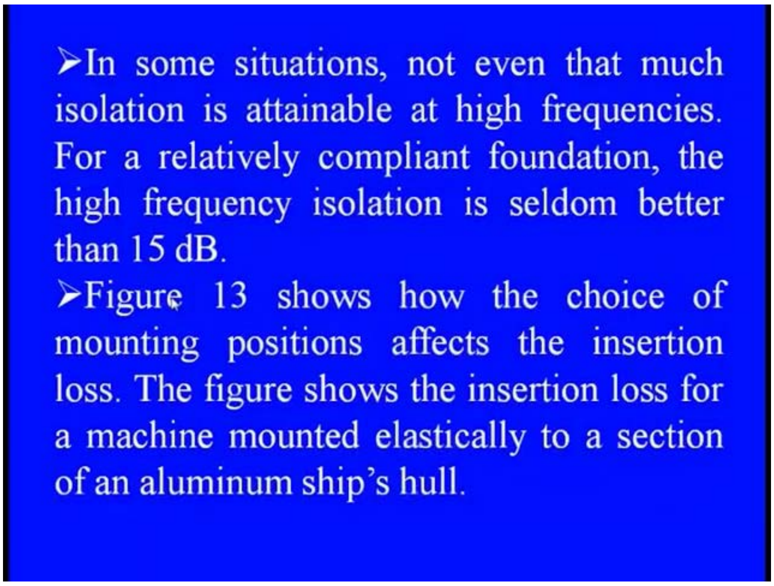

But in some situation, not even that much isolation is attainable at high frequencies. For a relatively compliant foundation, the higher frequency isolation is always better than the 15 dB. So, certainly sometimes when we are trying to apply those conditions with the isolator, we need to see that at higher frequency what exactly the attainable isolations. We are going to show you one more figure in which we can see that, how the mounting positions are being there and when they are changing, just to reduce the vibration oscillation, how the insertion losses are being varied. And also you see here, we can simplify find from this analysis that, the insertion looses for a machine mounting elastically to a system is always having some kind of tuning with the aluminum ship's hull.

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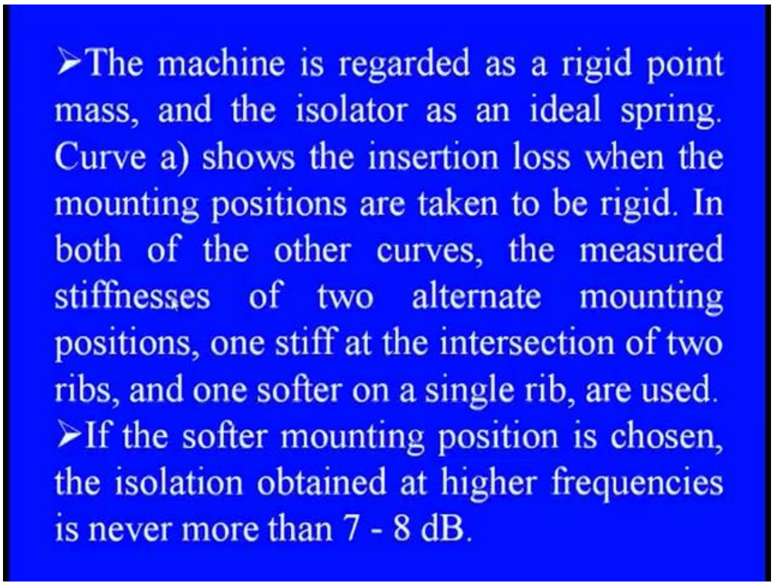

So, you see here we you know like, in this particular diagram which I am going to show you on the next slide, we can simply you know like consider the machine as the rigid point mass and the isolator, which is being there in between the foundation and the machine is an ideal spring. So, in that the curve, the first part of the curve a is clearly showing the insertion loss, when the mounting positions are being taken as the rigid.

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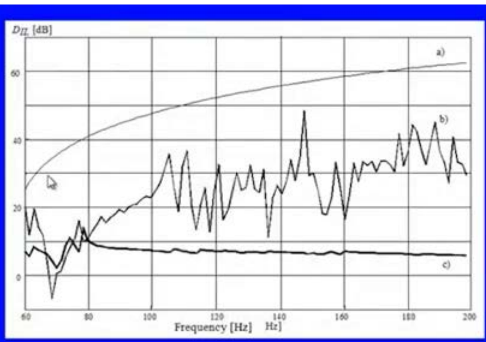

Figure 13 Insertion loss for vibration isolation in a stiffened ship construction. The results clearly show that an inappropriate choice of the mounting position can degrade the vibration isolation. a) Rigid foundation; b) Flexible foundation; mounting at the intersection of two ribs; c) Flexible foundation, mounting to a single rib. [2]

So, you can see that when it is being rigid, how the non-linear variation is there in the insertion losses, along with the frequencies. Because, the rigid foundation is always allowing the transmission is faster and you see here, whatever you know like the isolation features are there, they are not absolutely compatible to the systems.

Second, when we are taking the curve b, which is showing for the flexible mounting, when the flexible mountings are there certainly we know that, the deformation, the actual deformation with the vibration transmission in isolator, is a non-linear feature. So, certainly you see here when we are trying to see these things, the curve it is clearly says that whatever the variation then, this non-linearity is coming due to the variation in the stiffness and this is stiffness variation is of non-linear nature.

So, you know like the insertion at these two ribs, in which one is softer or the, we can say the stiff rib is clearly showing the non-linear variation. And the third curve, which is the c part is also showing the flexible foundation, but the rib is just one, there is no compounding ring, rib in which you, in which we have the flexible or the rigid stiffness.

So, you see we can say that when you have the two ribs of different nature, certainly more and more non-linearity is there, when we are going for the higher frequencies. And these higher frequencies are clearly you know like, oscillating in such a non-linear way that, the controls are not that effective, the insertion losses are quite significant. But with the single rib we can say that, even the flexible foundation is sufficient enough to absorb this and isolation can be effectively obtained at you see here, somewhere near around the 7 to 8 decibel sound.

And even you see, when we are using heavy machine vibrations, when you see you know like, the heavy machines are there and they are oscillating. So, when we are keeping the pillars in that means, the two ribs or somewhat you see, you know like the different transmitting media along with that, then we can straight way control the vibration, which are spreading through the structural member.

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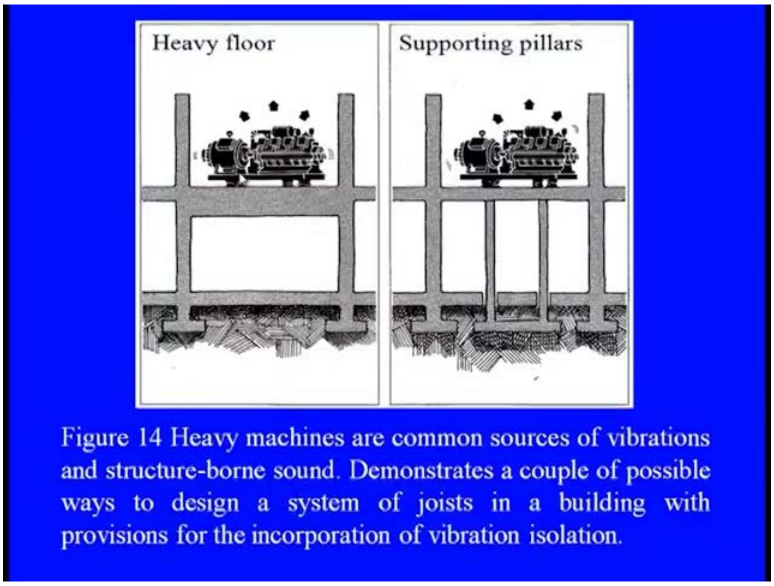

So, you can see that on the diagram, when you have the heavy floor and you see the machine on which this is there, when it is being you know like, under the exciting feature, the transmission is quite significant. At the source you see here, we have clearly the more excitation and the same time you see here this transmission is quite rapid, but when we are keeping instead of the heavy floor, when we are keeping a uniform floor even just below the machine as the foundation.

If you are keeping the ribs, then you see here or the joists we can say in the building, then we can say that the vibration isolation is quite significant because these joists can provide some kind of you know like, the attached masses. And these can be straight way absorbed whatever because these are the, a concrete feature. So, they can absorb straight way whatever, the exciting frequencies are coming down to the system. And the same time even whatever you know like, these sound waves are there, they are equally spread in all these four pillars, which are being there under the foundation of the machine.

So, this is you know like one of the practical example, in which we can say that instead of having the heavy floor for a rigid support or something. It is better to have a flexible support with the more ribs or the joists so that, the transmission can be bifurcated and the absorb, absorption of this energy can be effectively placed.

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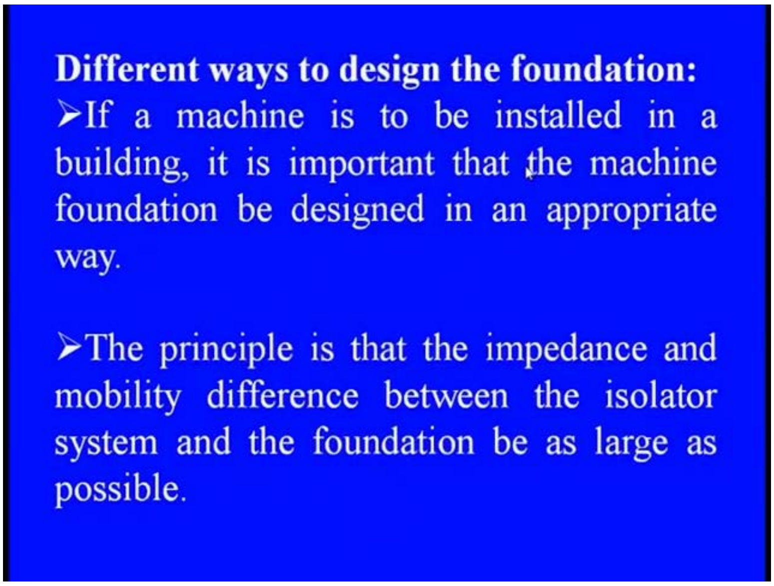

So, if a machine to be installed in the building, we need to see the machine foundation in such a way that, that whatever you see, the impedance and the mobility differences are being coming out between the isolator and the foundation. We need to keep these impedances and mobility difference must be as high as possible because then you see here, most of the absorption can be easily taken place.

So, this is one of the, we can say the foundation design principle that the two properties needs to be calculated, the impedance and the mobility. And you see here, the difference between these two terms for a perfect isolator or isolation system, the difference must be as high as possible. So, we can connect this into two main approaches, just to provide the extra heavy joists in the machine room first or to stiffen them, with the braces directly supported by the bedrock.

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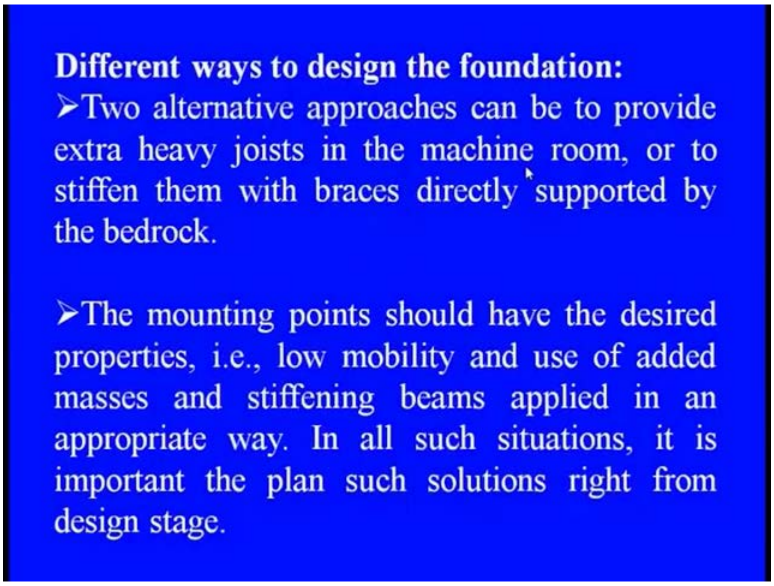

So, two things are there and both are effective first to provide the extra joists, heavy joists in the machine room so that, it will provide a strong support in that or to stiffen, if we cannot provide this according to the space then, we can stiffen those foundation with the braces, which are directly supported by the bedrock, whatever you see the bedrocks are there, we can directly support. The mounting point should have the desired properties, when we are doing this first, the low mobility because if the high mobility is there, then it is not a good isolator. And also with this low mobility, the use of added masses or any you know like, we can say the stiffening beams can be directly applied according to the appropriate way, which is being given to the application.

So, in these situation whether you see we are adding the masses, whether we are just trying to pull down the mobility or when we are adding the stiffener features to the beam. It is really important, the plan in such a way that, the solution should be appropriate, it should be compatible at the design state, stage. And the same time you see here, we can control the vibration isolation in an effective way.

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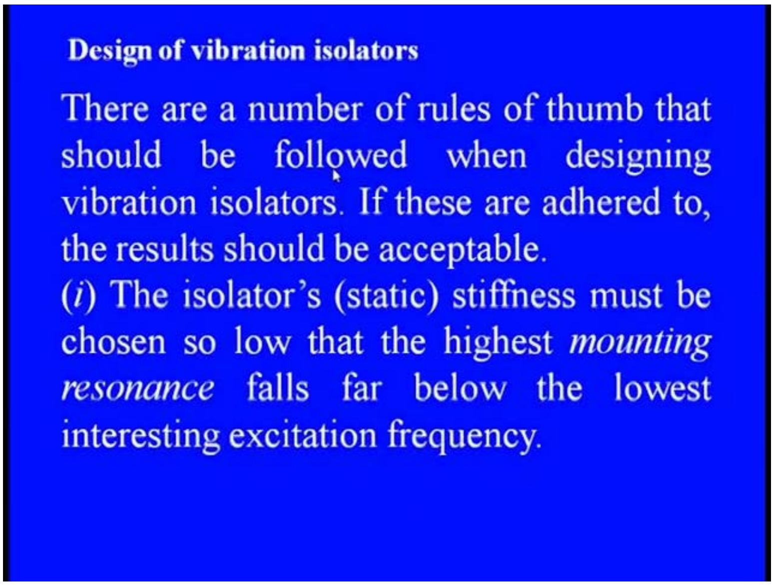

So, you see here in both the ways are equally effective in those terms. There are number of you see thumb rules for this, which we can directly follow while designing the vibration isolators. So, in the design processor we need to see that, whatever the vibration results are coming in terms of responses, it should be acceptable in one way. So, what are the design parameters or the processes in that? First, the isolator which is of the static nature, we can see the stiffness must be chosen so low that, the highest mounting resonances falls below the lowest, the intersecting resonant exciting frequencies. So, again in that you see here we need to say that, whenever we are keeping the stiffness as low as we can, we can say that, whatever the mounting resonances are there, they are always being low, than the exciting frequencies.

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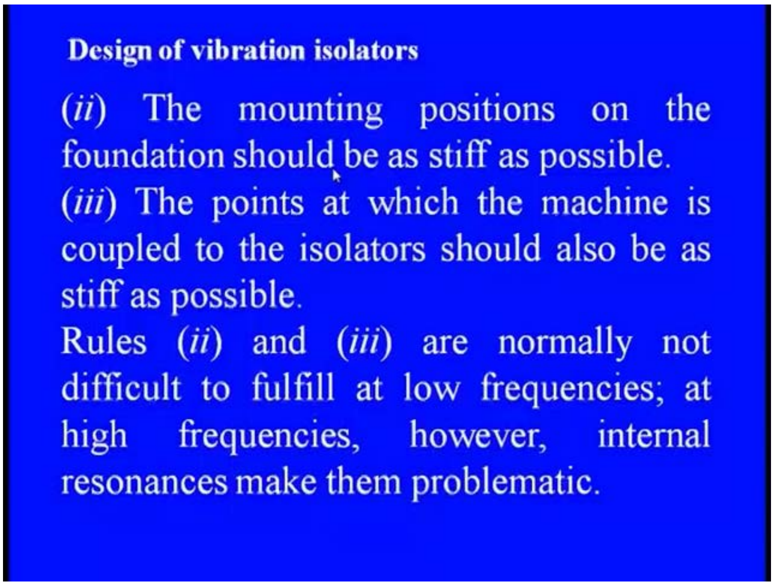

Second, the mounting position, the mounting position on the foundation should be maximum stiffer, which we can you see here provide so that, if it is you see less stiff on the mounting position or the found it is always giving the flexible foundation. And then you see here, the excitations will be of significant. Third, the design of isolator, the point at which the machine is coupled with the isolator it, it should also be as stiff as we can provide.

Because in both the cases, when we are talking about the machine, the mounting position or the connecting points then, normally not difficult to fulfill those things. Because, we know that at the low frequency or at high frequency, the internal resonances when it is being happening during excitation, irrespective of you know like the lower, higher, they are always creating the huge impact on those things. And finally you see here, the isolator should be designed in such a way that the first internal anti resonance, whatever you see the anti-resonances are coming at the first exciting frequency fall well above the highest excitation frequency of our own interest. Say, you see we want to design up to 300 hertz or 2000 hertz, it should be falling below that.

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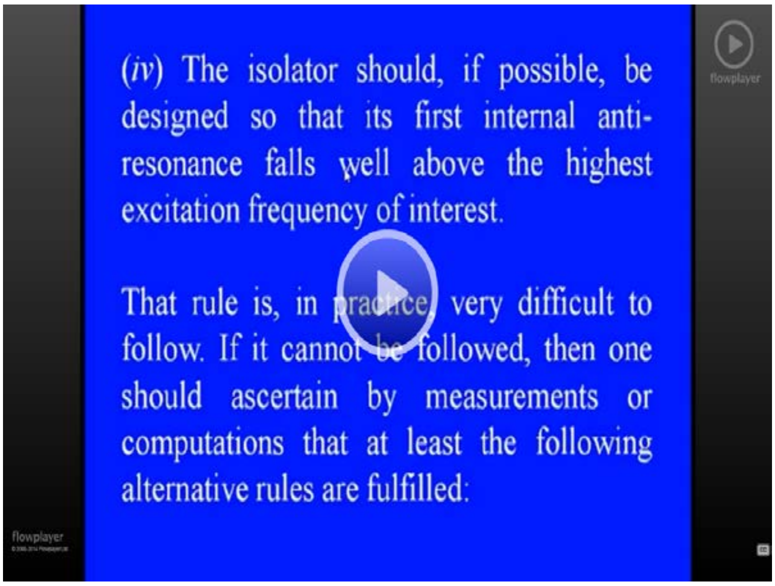

But this rule is very difficult to follow and if we cannot follow this, then we can ascertain these things by simply measurement or we can say by computing the characteristic rules that, at least the alternative rules can be fulfilled. Like, we can just go if it is at the low frequency or higher frequency the rules can be straightaway changes accordingly.

The fifth rule, the isolator must be designed in such a way that, the internal resonances do not coincide with the strong components of the exciting spectrum. Because, if they coincide with that, then those strong components will be at the resonant frequency and then, the huge amount of energy will be explode in that way. And they are creating huge oscillation at that point. Sixth point, the isolator must be designed in such a way that, the anti resonant frequency should not be coincide as we discussed, with the resonant frequency of the foundation. Because, if it coincide with the resonant frequency of the, this foundation then, we have a clear excitation of highest level and this excitation will transmit at the faster rate.

So, we can say that we need to adopt all six methods for designing the isolator at the appropriate place and according to, what kind of you see you know like, the system design is. And in addition to these rules, there are various constraints which are related to geometric strength and the stability feature, as we discussed in the previous lecture, they need to be considered here. Because, they have direct impact on the design of this vibration isolator and when we are designing these things, we have to be very careful for these constraints as well.

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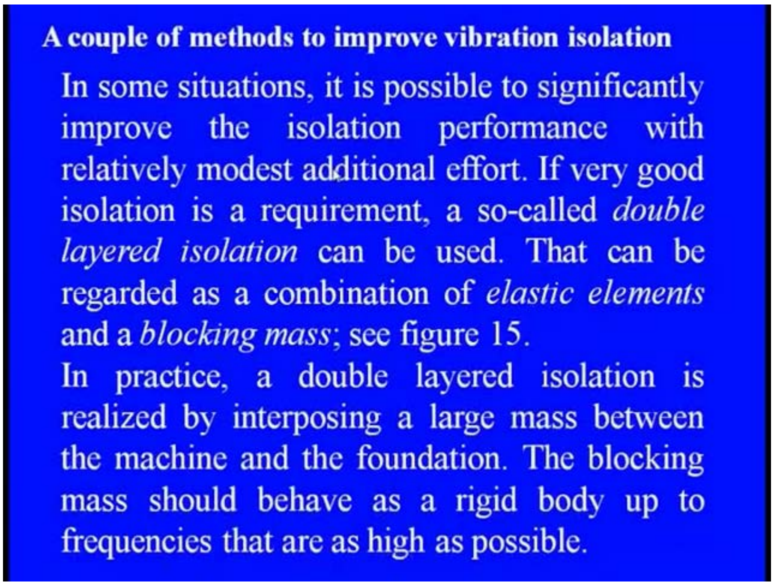

But in some situations, it is always possible to improve the isolation performance with some effort. If we have a very good isolator in our requirement say, or we can say that we just want a multiple layered, double layered we can say, isolation. Then, we need to go with the elastic elements. And the masses and this is a very common scenario by the way because we know that whenever we are trying to isolate all types of frequencies. May be, we know that the system is exciting at the lower frequency and the same time it is exciting, when it is during the operation it can go beyond certain higher frequencies as well.

So, we need to protect the system by these excitation frequencies, by adopting the multi layer isolators, the two layer or the three layer in that, we can provide either the spring as the isolator material or the damping as isolator material or the masses itself, the blocking masses. So, double layered isolation is really important and it is being realized by interposing a large mass between the machine and the foundation. Because you see here, when you have the higher order harmonics, the frequencies we need to suppress those frequencies and there is an added masses to be there, as we have seen in previous cases. And the blocking mass should behave as a rigid body, up to those frequencies for the appropriate level.

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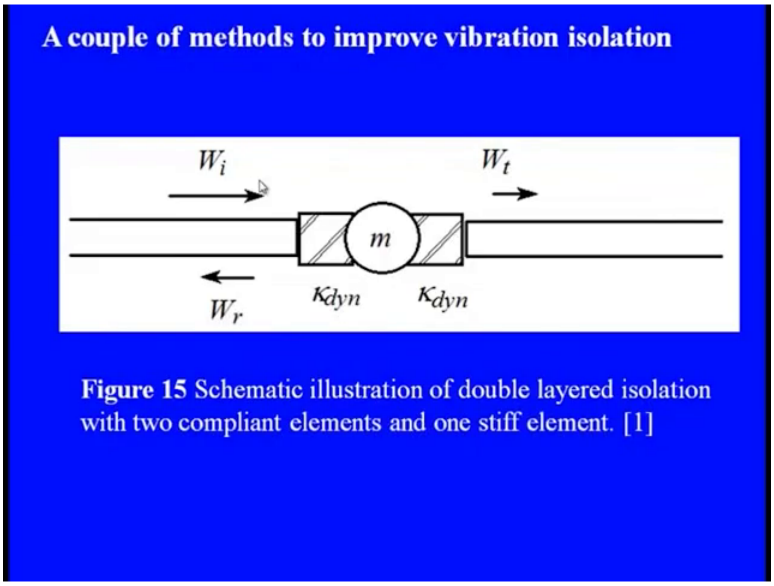

So, you see we can say that, you know like, this is the diagram in which it is clear that, you see, when the things are moving the stiffness, the ,you know like, what are the spring stiffness's are there, they are even the dynamic stiffness's, but they are not appropriate.

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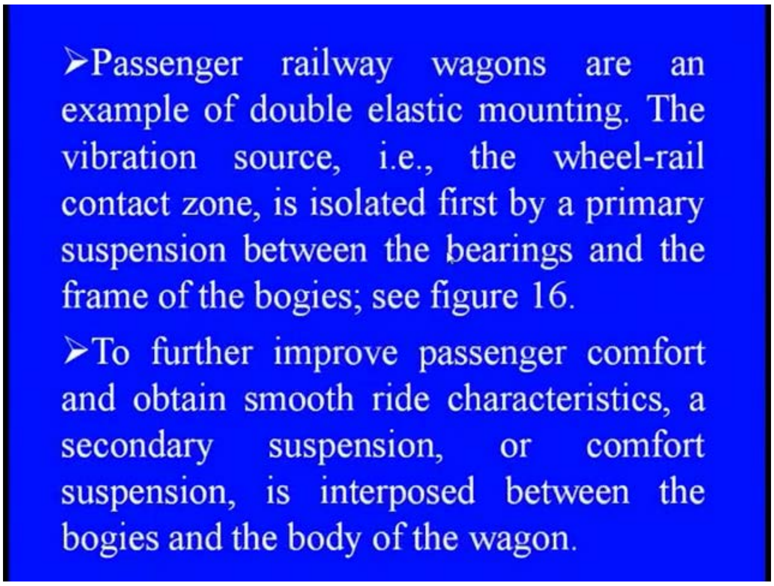

So, we need to adopt the masses so that, the reflecting feature of the wave is quite significant. And whatever the transmission is there, the w t, it should be as low as possible. And this is known as, we have the spring, we have the masses in between and this is known as the double layer isolation where, we have the mass and the stiff element together, in the series way.

And this is a pretty common you see, you know like example, like the passenger railway wagons are there, in which we have the double elastic mountings. The vibration source, which is nothing but you see, the rail wheel interaction and when you see this, this rapid interaction under the you know like, the cyclic loading, it is quite continuous. So, it should be you see here isolated because when it is transmitted right from the rail wheel interaction to the bogie sheet and all, certainly it will create the discomfort to the passenger.

So, first we need to isolate by the primary suspension between the bearings and the frame of bogie. So, you see here this isolation can be easily provided by some isolating material, when we can keep those things. And to further improve the passenger comfort, we can straight way obtain a secondary suspension system, in which we can provide a different isolating material than the first one so that, whatever the frequency, which are simply refined by the first, it can be absorbed at the second one.

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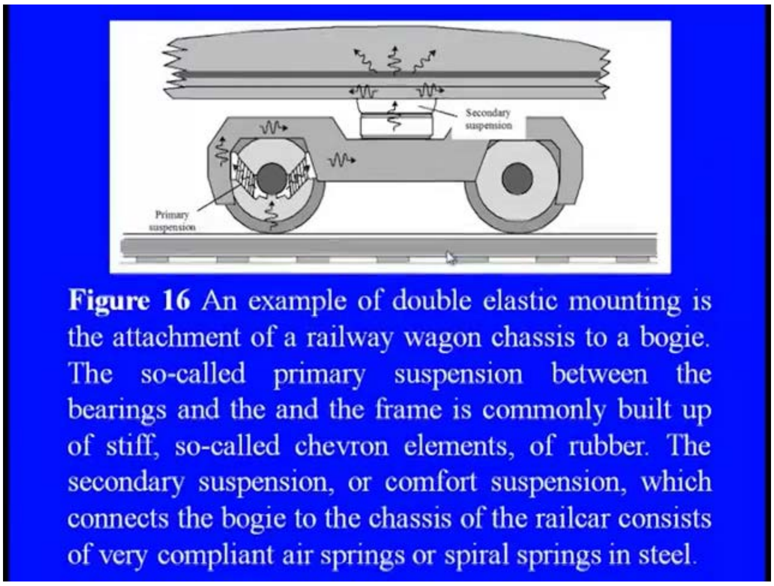

So, as you can see on the diagram, this is the railway vehicle in which we have the primary suspension in between the axle and the wheel, you see here. This is what it is, the primary suspension in which you see, you know like, we have a clear you know like, the railway bogie chassis with the, you know like, we can say the wagon is there. The primary suspension is absolutely acted in between the bearings and the frame. So, we have you see you know like, generally we know that it is a taper roller bearing, in which you see the line contacts are there. And you see you know like, this taper roller bearing is always in generally either the spherical way or the, a cylindrical way.

These rolling bearings have a clear feature because of the line contact, they can run smoothly, but even you see they have the line contact, the stiffness variation is quite significant and the excitation is really significant. So, we need to provide in between the bearing and the frame there is you see, you know like, we can say a element is there, that is called the chevron elements. And there is a rubber in between it is been provided, but you see here, even after that since it is a rigid structure, there is a clear transmission of the vibrations are. So, in between the wagon or we can say the passenger bogie and this, there is you know like, the secondary damping is provided.

So, the secondary suspension or we can say, you know like, sometimes we are saying because it provides the comfortable, the comfort suspension is being connected with the bogie to the, from the bogie to chassis in the railway coaches. And since you see here, this is of the low exciting, low frequency vibration in the excitation, the spring is good enough to suppress those things. So, the, as far as the secondary suspension system is concerned as you can see on the diagram, the springs are good enough for these.

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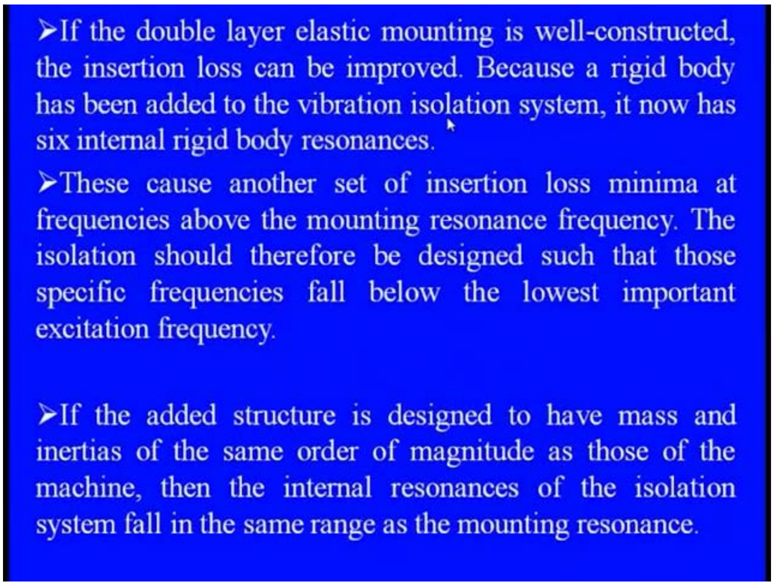

So, this is the example which clearly shows that, to suppress the vibration we need two isolators. So, that is why you see here we can say that, the double elastic mountings are absolutely required in the passenger bogies. And the double layer elastic mounting is always gives, the less amount of insertion losses and because of that you see here, even we have a rigid body, which is being added to the vibration isolation system, can be even improved with their own resonance frequencies. And when you have the rigid body resonances, the internal rigid body resonances, they can cause the, another set of the insertion losses. And we can put you see here, we can reduce those things whatever you know like, the insertion losses are coming due to the internal resonances, by simply putting the, we can say the isolators, exactly mounting with the resonant frequency.

So, the damper is one of the good features in that. So, even the material damping which is coming out due to the bogie or something, can be at, as a good damper. Even in the passenger bogie there are you see, the high grade viscous soils are there, in the viscous damper to suppress the internal resonances in that. And the isolation should therefore be designed in such a way that, these specific frequencies which is coming out you know like, from the internal resonances can be immediately dumped out. And if the added structure is designed to have the mass and the inertias of some order of magnitude then, the internal resonance system from the isolation point of view, fall in some range from the mounting resonances.

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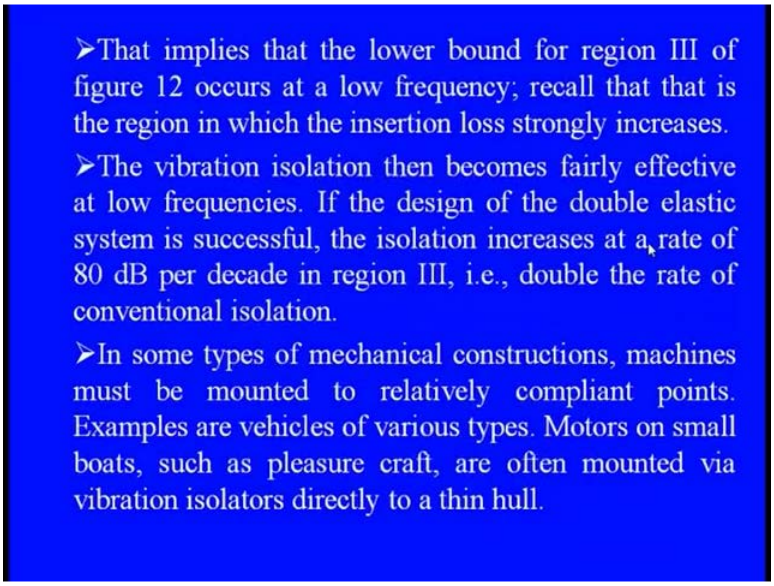

So, how you see they are been connected, what exactly the suppressing masses are there, how the dampers are there, the, that is. The entire system should be perfectly designed in a robust way so that, every component irrespective of the mass damper or the spring, the primary or secondary suspension system, they can be effectively communicate the entire vibration, towards the system itself.

So, we, now we can say that, the lower bend for any region you see, which I am going to show you means, the lower frequency bend can have you see, the strong insertion losses. And when you see we are increasing the frequencies towards that, the insertion losses are increasing.

I am going to show you the diagram, the vibration isolation in that is really effective at the lower frequency. And if we are just going with the double elastic mountings for vibration isolation, it is always being effective and it can be, you see, you know like, the whatever, you know like, the isolation can be increased, when we are just going below the 80 dB of sound. But in some types of you see, the mechanical construction, the machine must be mounted to a relatively compliant points. As we can say that motor on the small boats such as you see, you know like, we can say, the pleasure craft or you know like, whatever the things are there. We can put directly a thin hole in between the motor and you see, the foundation so that, the isolation can be provided in a effective way.

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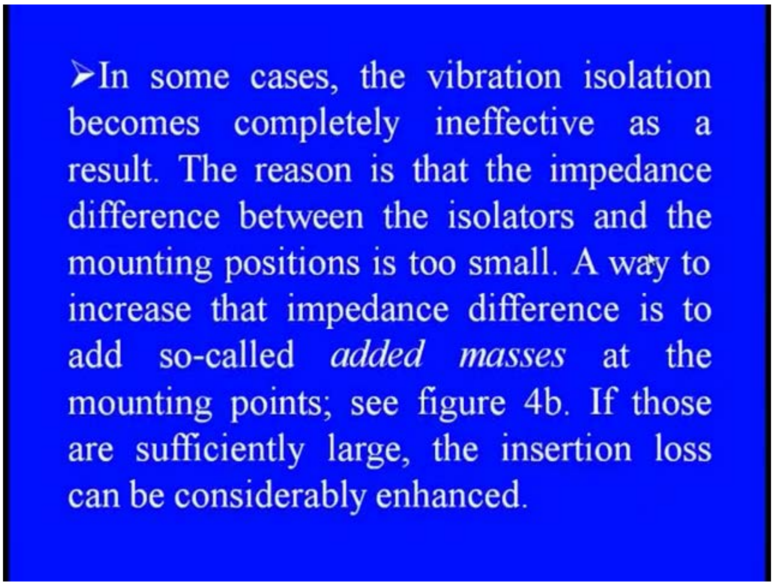

But in some cases you see, the vibration isolation becomes ineffective, it is just because of as we discussed, the impedance differences between the isolator and the mountings is so small. And if you want to have a good isolation, we need to keep this, the difference between the impedance and mobility, must be high. So, if you want to increase the impedances, difference you see, in between you see, you know like, those foundations and the machine, we need to add the masses at the mounting points. And if it is you see, you know like, the large enough according to the system, the insertion losses can be straight way drop down.

So, you see here, when we are going to the market we know that, there are variety of isolators are available. We can simply you know like categorized into the various ways like the coil springs, the rubber isolators, the gas spring. Even you see here, when we are just trying to see in the, this we can say some kind of the oil springs or the, this rubber isolators, the variety of polymers and the other types of you see, the rubber materials are there. And they have you see, the lots of flexibility in terms of the absorption of the energy.

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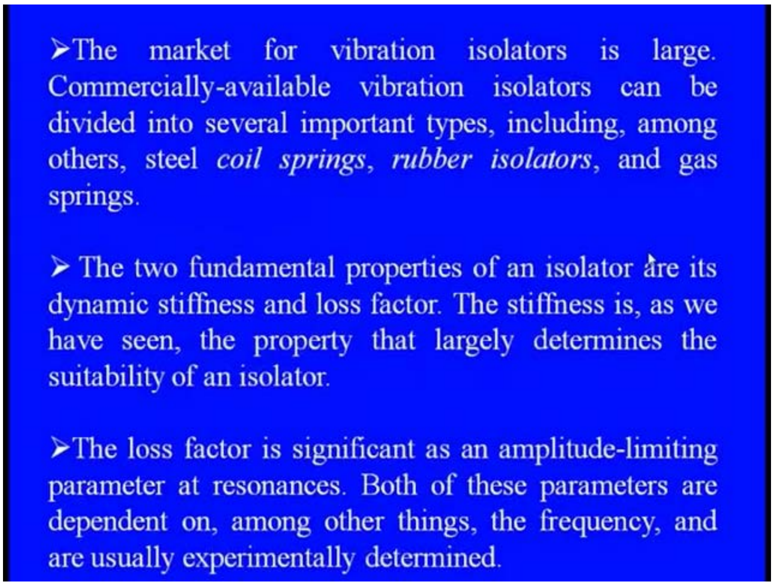

So, there are two fundamental properties of an isolator, which are to be considered. One, what is the dynamic stiffness and second, what is the loss factor in this. So, the stiffness which is one of the important property there, can largely be determined by what exactly the amount of force and the corresponding deformation. And it is appropriate to evaluate those things because you see here, we need to check it out that whether, it is suitable with the isolator or not. So, this is one of the material property of the system itself.

Second, the loss factor, it is one of the significant part as an amplitude limiting parameter, at the resonance. And both the parameters, like the stiffness and the loss factor, the dynamic stiffness we should say here because it is under the, you know like, the vibrating feature. So, both the parameters are absolutely depend, demand, dependant on various other things like the frequency exciting and you see here, the amplitude of those features and we need to find out the experimentally those things.

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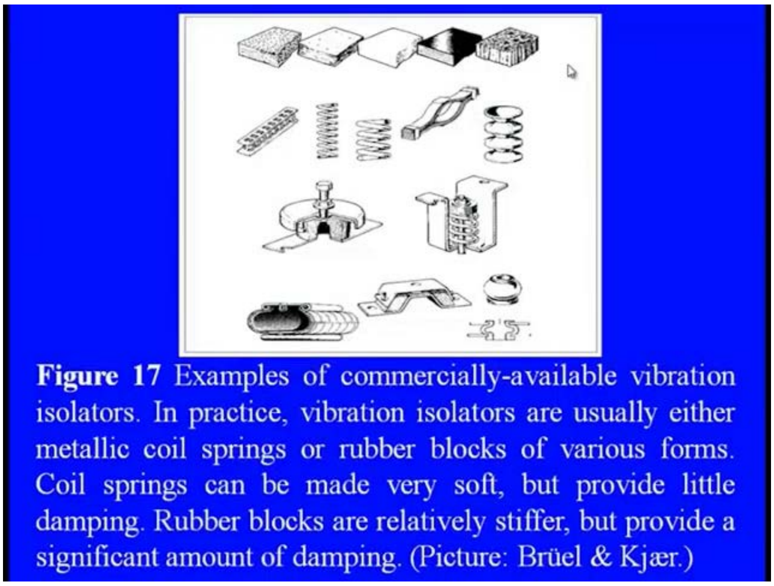

So, you can see on the screen various commercially available vibration isolators are there. So, we can say they are either in the form of metallic coil springs or the rubber blocks or these coil springs can be made from very soft material. And also you see here, these soft materials can provide, some kind of material damping. The rubber blocks are somewhat more, we can say stiffer, but also provide the greater amount of damping there itself. So, all these irrespective of the first, second, third and fourth kind of you see, the isolators according to the location, according to the exciting frequencies, according to the oscillation amplitude, we can choose these and we can apply straightaway.

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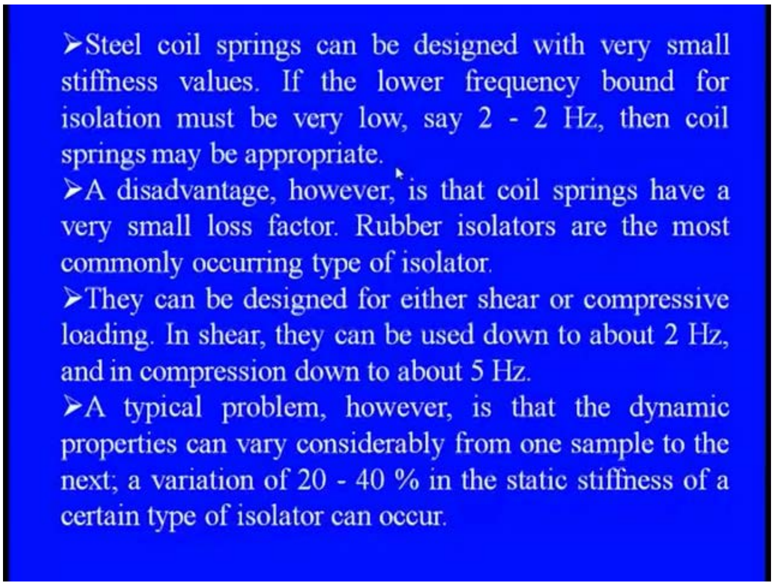

So, when we are talking about the steel coil spring, it can be designed with the very small stiffness value. And if the frequency excitation is quite low, low bounded particular, then we can straight way apply even at the exciting frequencies of 2 to minus 2 hertz the, these coil springs are absolutely okay. But there is a drawback in that, that these coil springs have very small loss factor. So, sometimes even for this kind of systems, the rubber isolators can be effectively used in that. And these can be designed for either shear or compressive loading as well.

So, this is again you see here, when we are just talking about, just load stiffness or loss, loss factor, we need to check it out the kind of loading whether, it is compressive nature or the shearing nature. Means, the vertical or the parallel loads or the normal or the parallel loads are there. And in shear, this can be used just, you know like even less than the 2 hertz and in compression, it can be go up to the 5 hertz and they can down entire frequencies up to that. So, even for the dynamic properties which are you know like, varying accordingly, there is a variation of 20 to 40 percent static stiffness, with the isolators and we can even go up to that you see here.

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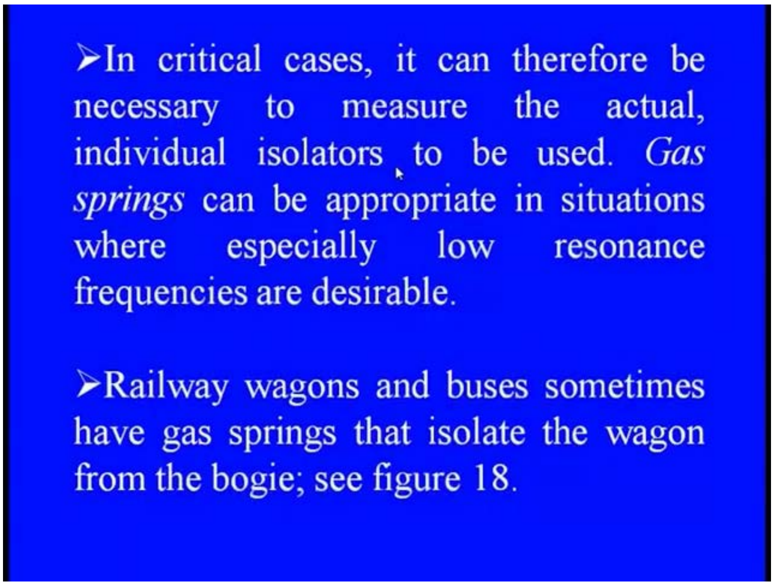

But in some of the critical cases, there is a necessity to measure the actual individual isolator. So, sometimes you see the gas spring are absolutely appropriate, when the low resonant frequencies are being desiring. So, the railway wagons and the buses, they have the gas spring because it can isolate the, isolate the bogie from the wagon. And this is what you see one of the effective way, when we are using the hollow bogie and the air is acting as a gas you know like, we can say whatever the air and other parts they can be act as a gas spring.

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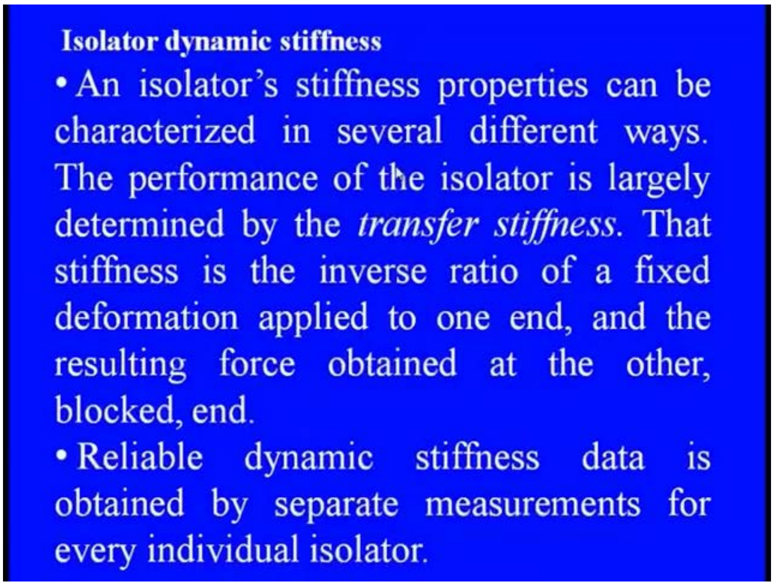

Now we are going into the next section, that is the isolator dynamic stiffness. An isolator stiffness properties can be characterized by various ways, the performance of isolator is largely determined the, by the transfer stiffness. Because you see here, it is being transforming those things and that stiffness is nothing but the inverse ratio of the fixed deformation, which is being applied to one end. And the resulting force is you know like, obtained at the other blocked end. So, we need to check it out that you see here, how the transfer stiffness is being occurred and how it is being applied to the system. And then, there is a reliable dynamic stiffness data should be obtained, in a separate way for every individual isolator, for appropriate design of isolator, under the dynamic stiffness.

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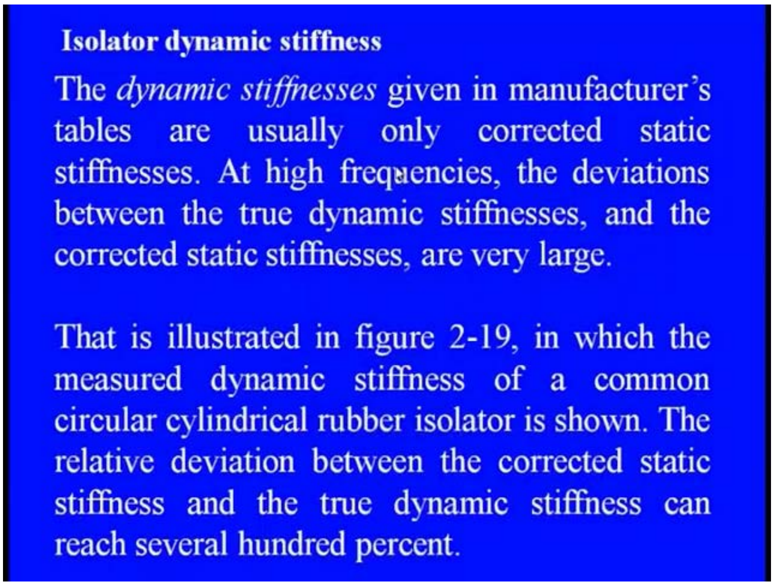

Because, this dynamic stiffness is always being there in the manufacturer you know like, when the manufacturer is just providing the data, it is always being there, but it is only connected to the static stiffness. And at the higher frequency, the deviation between the true dynamic stiffness and the corrected stiffness is always high.

So, we have to be very careful while designing those things, that what exactly the differences are being coming out, even at the low frequency, at the resonant frequency and the higher frequencies, in between, the difference between the dynamic stiffness and the static stiffness. So, we are going to show that you see here, in which the dynamic stiffness of a common circular cylindrical, rather I should say rubber isolators are being used. And it is a relative we can say deviation is there, in between the corrected static stiffness and the true dynamic stiffness.

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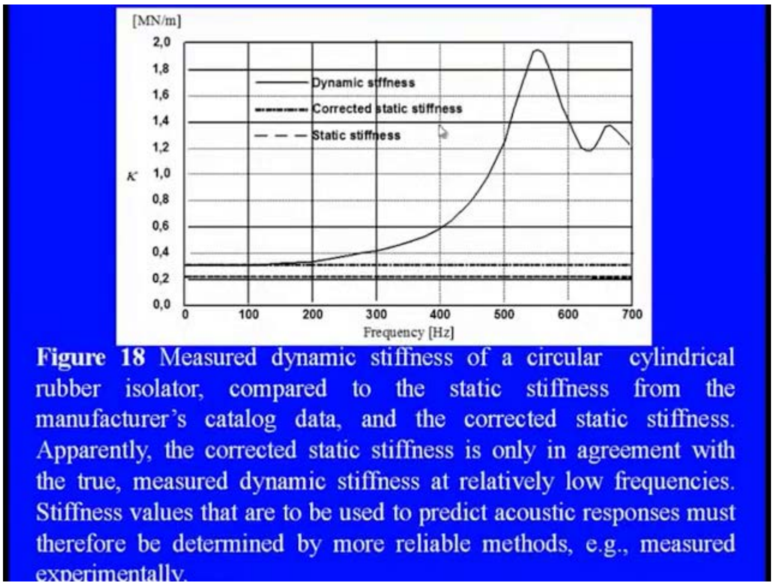

Figure 18 Measured dynamic stiffness of a circular cylindrical rubber isolator, compared to the static stiffness from the manufacturer's catalog data, and the corrected static stiffness. Apparently, the corrected static stiffness is only in agreement with the true, measured dynamic stiffness at relatively low frequencies. Stiffness values that are to be used to predict acoustic responses must therefore be determined by more reliable methods, e.g., measured experimentally.

And then you see, we can say that you see, this is what it is, the dark the continuous line is clearly showing the dynamic stiffness. The dotted, the closed dotted points is just showing the corrected static stiffness and the clear dotted lines are showing these things. So, we have you see in this the major dynamic stiffness of circular cylindrical rubber isolator just shows that, when we are comparing these two, the static stiffness from the measured we can say, the catalog data.

So, it is just showing that how the variation is there in the dynamic stiffness at the higher harmonic. So, at the lower frequencies we can find that the differences almost negligible, they are absolutely close, both the corrected static stiffness and the dynamic stiffness, in this region. But as we are moving towards the higher frequencies, right from 300 hertz and above then, we can see that, there is a clear variation.

The stiffness values can be used to predict the acoustic responses. And we can straight way find, the more reliable method in that, that you see here, when we are going for higher harmonics. The dynamic stiffness's are always giving the correct value as compared to the stick, the even corrected stiffness, the static stiffness or the static stiffness as well. So, this is all about you see, the isolator stiffness's.

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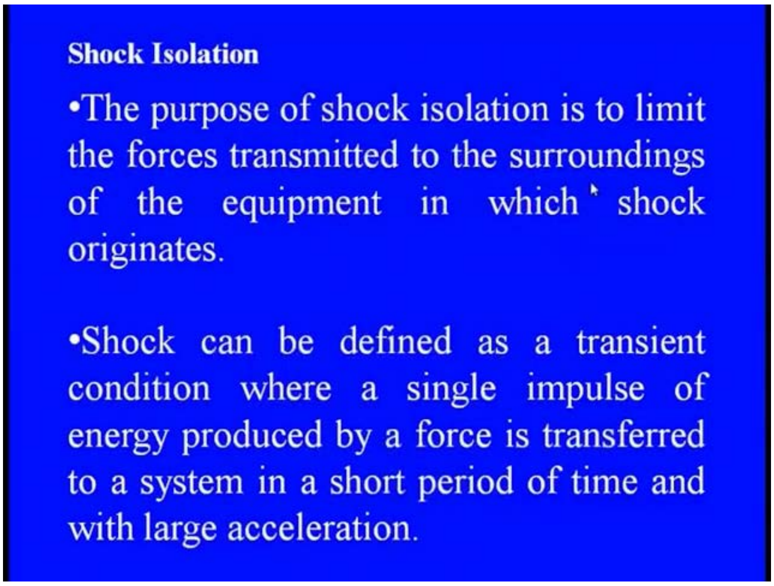

Now, if you are going for vibration isolation again, the shock loading because the purpose of shock isolation is just to limit the force transmission to the surrounding of the equipment, when the shock is originated. Because, at the time of shock there is a huge amount of energy and this energy you know like, it is a kind of adrupt energy. And it appears in a just, you know like, the significant way.

So, shock, if you want to shock now, if you want to define the shock, the shock can be defined as the transient condition with some, we can say, a kind of impulse forces, produces the huge amount of energy. And this is being transferred to the system, in a very shorter period and if you see here, we have a good you know like, the transmission system, the solid transmission system.

Then it will be you know like, transmitted very rapidly because not only it has the maximum energy, but also it has the greater amount of acceleration. So, it can damage all the surrounding because of the huge amount of energy. So, the reduction of the shock can be obtained by using the isolator, which can result you see in the storage of the shock energy, within the isolator and then, they release the energy over the long period of time.

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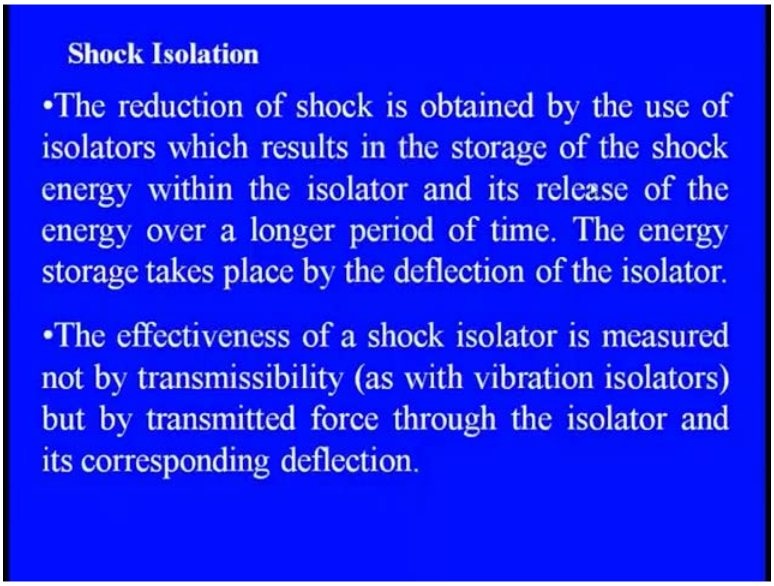

Because you see here, it should have the characteristic to restoring the energy for the longer time. And the energy takes place by the deflection of the isolator, should be acted as the storage one. So, if you are talking about the effectiveness of such kind of the isolator, the shock isolator cannot be straight way measured by you know like, we can say the transmissibility, in which you see, the clear transmission is there.

But even you see it can be defined, the effectiveness can be defined by the transmitted force, which is being you know like, passing through the isolator and its corresponding deflection. So, when we are going with the normal kind of isolator then, the transmissibility is one of the, if you know like, effective tool to analyze the performance of the system. But here we need to check it out, that how much time will it take, to transmit the huge amount of energy to the surrounding. So, what is the absorption capacity of the isolator per unit time.

So, there are two classes of this shock to be considered here. One, when the shock characterized by the motion of a support, where the shock isolator reduces the severity of shock, which is experienced by the equipment on the support. So, this is one way and second, the shock can be characterized by the forces, which are being applied or originated within the system where, the isolator reduces the severity of shock, which is being experienced by the support. So, both are you see you know like the characteristics can be straight way used in that.

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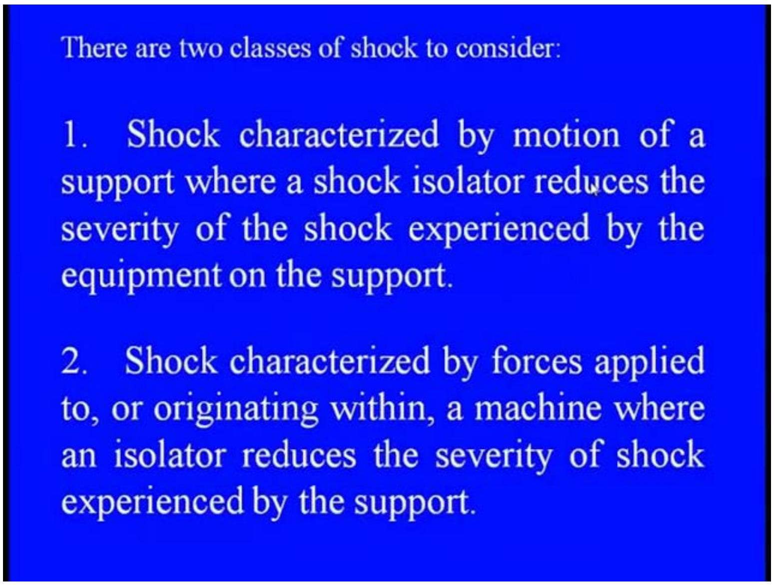

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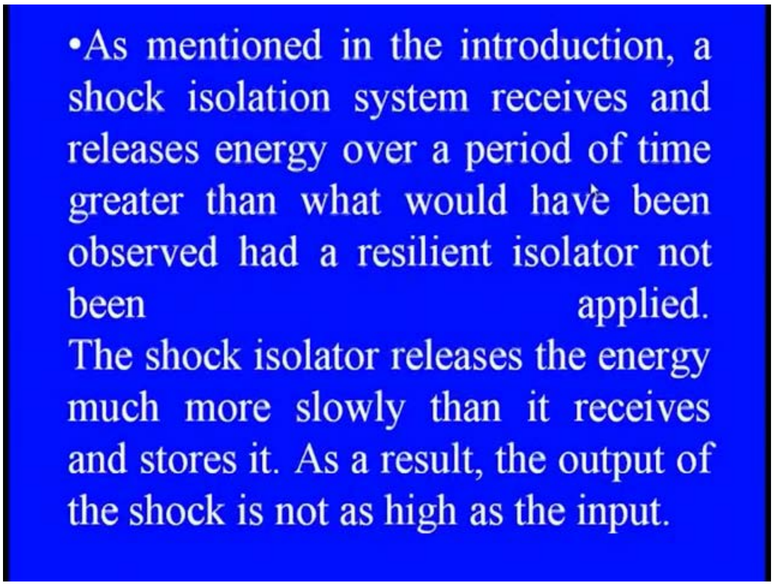

So, we can say that the shock isolation system receives and release both, energy over a period of time, which is more than, what generally we have seen for the resilient isolator. So, shock isolator which releases the energy in a very slow rate, then it receives and stored it. And we can say that, you know like, the shock isolator the output of this, you know like, shock is not as high as the input is. And then, you see here sometimes, when we see that the over damping phenomena in which you see here, you know like, the system is coming to the steady state in a very longer period because the energy released is so slow, we can choose in that way.

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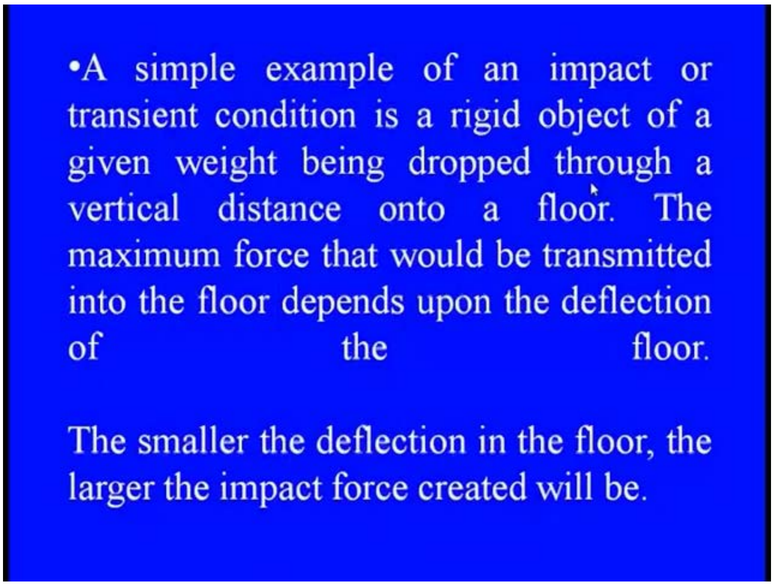

So, in general if you just want to take an example, an impact or the transient condition, is a rigid object of given weight being dropped, through a vertical distance onto the floor say. And the maximum force that would be transmitted to the floor depending upon the deflection of the floor, the smaller deflection in the floor means, the larger impact force created.

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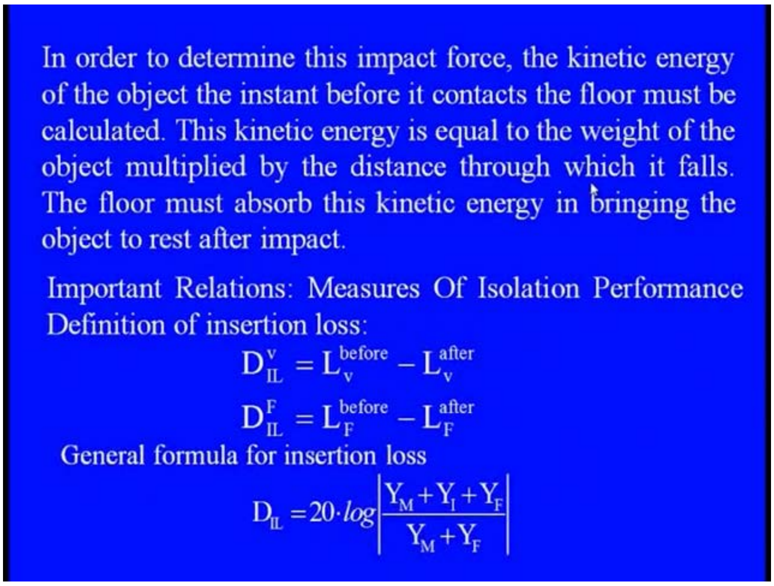

So, in order to define this one, that how much you see the impact forces are there and how much kinetic energy of the object is being transmitted, by the object to the floor. We need to check it out, the kinetic energy of the, you know like, the object which should be equal to the weight of the object multiplied by the distance, as we know that. And the floor must be absorbed this kinetic energy, just bringing down the object towards the, just rest after each impact, because every impact there is a loose of the energy and this energy loss is nothing but equal to the absorption of the energy by the isolator.

So, we can simply define this as the major of you see, the isolation performances we know that, the insertion loss for such kind of system, in which the shocking, the shock loading is there, is nothing but equals to the Lv minus Lv before minus Lv after. So, it is nothing but equals to the level of velocity before and after, is giving the insertion loss or else even the forces also can be even applied to measure the isolation performance with the insertion losses. Or else if we want to go as a generalized feature, the insertion loss DL is equals to 20 log YM plus YI plus YF divided by YM plus YF.

So, how much you see, you know like, the distance is there, how much we can see, the force is being applied in that and accordingly we can get this. So, the, you see, this is one of the effective way for the shock isolation that, if we want to absorb the energy as much as we can and then, if we want to release the energy for a longer time you see here. Then, the isolator should be of that nature and the perfect isolator is always depending on that, how much energy is being coming out, when the impact loading is there.

So, in this lecture we discussed about, few of the numerical problems of that and then also we discussed about that, how you see here, we can adopt appropriate isolator for the variety of you see the, you know like, with the, a combination of the machine. And also you see here, when we are going for the shock loading then, how we can adopt the isolators in that.

In the next lecture, now we are going to discuss about the other ways, the various other ways of isolator design. Because in that you see here, you know like, when we are trying to consider the insertion losses in between you see, you know like, we can say these two features, the machine and the foundation, when it is just transmitted before and after say, with the velocity of the force, even for the rigid or flexible mountings. Then, we also know that even at the lower frequency and higher frequency, it is not even appropriate measure, because the impedance and the mobility is also playing a key role and we just want to make the impedance difference with the mobility as high as possible. So, in the next lecture we are again going to solve some numerical problem based on that. And also, we will try to see some other applications in the real machines or the, we can say the real mechanical devices so that, an effective isolation can be done in that.

Thank you.